

Money activates reward circuits in cocaine addiction: A functional MRI study at 4 T

R. Z. Goldstein¹, S. A. Berry², A. C. Leskovjan¹, E. C. Caparelli¹, D. Tomasi¹, L. Chang¹, F. Telang¹, N. D. Volkow¹, N. K. Squires², T. Ernst¹

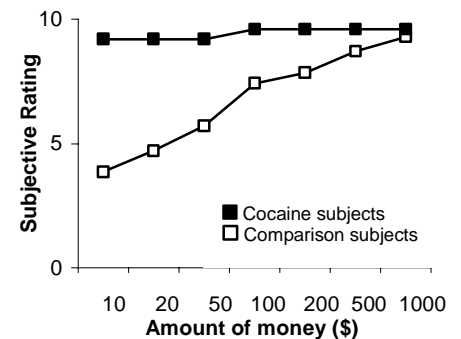
¹Brookhaven National Laboratory, Upton, NY, United States, ²SUNY at Stony Brook, Stony Brook, NY, United States

SYNOPSIS: In this fMRI study we examined modulation of the brain circuits underlying salience attribution by drug addiction. Subjects were 5 cocaine addicts and 7 healthy volunteers scanned while performing a Go/No-Go task under three levels of feedback for correct performance: no money (0 cent), low money (1 cent) and high money (45 cents). While there were no significant differences in brain activity between the high and low monetary conditions for either study group, the corticolimbic reward circuit (including the cingulate gyrus and basal ganglia) was activated by money in the cocaine group only, consistent with increased subjective value of money.

INTRODUCTION: Neuroimaging studies in drug addiction¹ have documented abnormalities primarily in the striato-thalamo-orbitofrontal circuit. The same corticolimbic circuit has been implicated in processing of reward salience such as when receiving monetary payoffs during game-playing tasks¹. We therefore hypothesized that the pattern of brain activity underlying perception of monetary reward/salience of feedback would be modified by cocaine addiction.

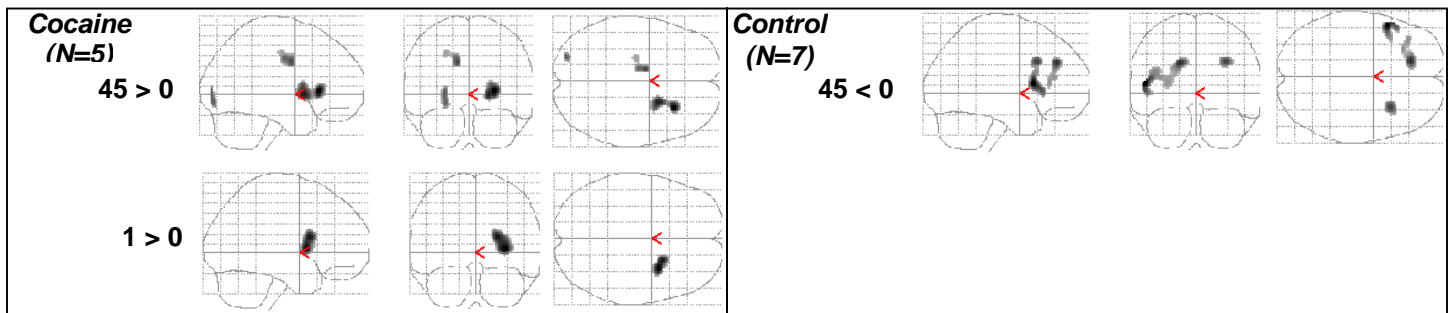
METHODS: Subjects Five men who fulfilled DSM-IV criteria for cocaine dependence (age 41±3 years, education 13±4 years) and seven healthy volunteers (age: 36±7 years, education: 15±2 years) completed the fMRI studies. The activation paradigm was a cued reaction time Go/No-Go task where the cue signaled whether a response was required to a subsequent target stimulus². Feedback (0 cent, 1 cent or 45 cents) was varied across blocks of trials. Order was pseudo-randomized and identical for all subjects. To simulate real-life motivational salience, subjects received up to \$50 for their performance on this task. Functional MRI was performed in a 4 Tesla whole-body MRI scanner by using a single-shot gradient-echo EPI sequence (TE/TR 20/3500, 4 mm slice thickness, 1 mm gap, typically 33 coronal slices, 64 x 64 matrix size, 3.125 mm in-plane resolution). The entire brain was successively scanned 91 or 101 times. Motion correction (up to 1 mm translation and 1° rotation), spatial normalization to the Talairach frame (using an optimized template that accounted for the signal loss in the frontal regions), smoothing (8 mm gaussian kernel), and calculation of activation maps corresponding to the contrasts between the three feedback conditions (45>0, 45>1, 1>0 and 45<0, 45<1, 1<0) were performed using SPM99.

RESULTS: Cocaine subjects: There were significant increases in BOLD signal in the right basal ganglia for the 45>0 (cluster size = 394; Z = 3.94; p-corrected < 0.05) and 1>0 (cluster size = 385; Z = 4.01; p-corrected < 0.05) contrasts. A signal increase in the left cingulate gyrus approached significance (cluster size = 156; Z = 3.55; p-uncorrected = 0.052) for the 45>0 contrast. There were no significant activations for the **Comparison subjects**. Nevertheless, signal decreases were observed in the left frontal cortex (cluster size = 231; Z = 4.12; p-corrected < 0.05) (45<0). There were no significant differences between the high and low monetary conditions (45>1 or 45<1) for either subject group. Results could not be attributed to variations in reaction time, accuracy, or subjective ratings of interest and excitement for the task (p's > 0.05). Rather, the subjective value of different amounts of money differed between the study groups (F=12.3, df = 2,18, p < 0.001) such that cocaine subjects (top row in figure on right) gave higher ratings to all 7 amounts of money.



CONCLUSIONS: Consistent with previous studies², our preliminary results suggest that monetary reward is associated with a different brain activation/deactivation pattern than a non-monetary feedback, involving primarily the striato-thalamo-orbitofrontal circuit. In cocaine addiction this corticolimbic reward circuit is activated by drugs and drug-conditioned cues (money), in parallel with an increased subjective value of money. Such hyper-responsiveness/increased salience attribution to money (and other drug-related cues) may underlie the inability to control behavior during periods of drug bingeing and relapse.

Figure. Glass brains of study subjects for three contrasts; threshold was set at T-score=3 and cluster size=50. Please note that there were no significant activations for the comparison subjects, possibly due to the small sample size.



REFERENCES:

1. Goldstein RZ, Volkow ND. Am J Psychiatry 2002;159: 1642-52.
2. Thut G, Schultz W, Roelcke U, et al. NeuroReport 1997;8: 1225-8.

ACKNOWLEDGMENTS: This study was partially supported by NIDA (1K23DA015517-01) and DOE (OBER). We also thank S. Arnold and JY. Ma for assistance with SPM analyses and LA. Cottone for assistance with task design.